1. INTRODUCTION AND PRINCIPAL RESULTS

William E. Benson, National Science Foundation, Washington, D.C.
and
Robert E. Sheridan, University of Delaware, Newark, Delaware

CRUISE DATA

D/V *Glomar Challenger* sailed from Norfolk, Virginia on 5 August 1975 and returned to Norfolk on 30 September 1975 to complete Leg 44 of the Deep Sea Drilling Project. The eleven holes drilled at Sites 388-392 (Figure 1) comprised the last scientific leg of the project's Phase III. Table 1 summarizes the drilling operations.

Leg 44A was a three-week "engineering trial" devoted to testing the overhauled *Glomar Challenger* and new hardware developed for the deeper penetration required during IPOD (International Phase of Ocean Drilling). The *Challenger* left Norfolk, Virginia, on 8 November 1975 and arrived in San Juan, Puerto Rico, on 27 November 1975. The scientific data obtained from drilling at Sites 393 and 394 (Figure 1) in the Blake-Bahama Basin is included in the present volume. Table 2 summarizes the Leg 44A drilling results.

BACKGROUND

The western part of the North Atlantic Ocean holds clues to some of the most intriguing questions in marine geology. But because the geologic problems are many and varied, the sites of Leg 44 were multipurpose in nature. We planned to drill different kinds of sites in several areas, each with its own set of objectives.

Our four major objectives were drilling: (1) the lower continental rise east of Cape Hatteras, where we hoped to get evidence for the origins of the continental rise hills, to prospect for carbonaceous and metalliferous sediments, and sample the basement between Sites 105 and 106 of Leg 11; (2) the Blake Nose, a spur of the Blake Plateau, to determine the nature, age, and origin of reef-like structures recognized on seismic profiles; (3) the Blake Outer Ridge, a long low ridge of sediments that forms the eastern boundary of the Blake-Bahama Basin, where we hoped to study the stratigraphy and sample supposed clathrates; and (4) the Blake-Bahama Basin, where we planned to sample the basement near the western edge of the magnetically quiet zone, as well as to continuously core the Lower Cretaceous and Jurassic formations, and to recover what we hoped would be the oldest sediments from any ocean basin.

A number of mechanical and operational failures denied us some of our aims. For example, several different mechanical failures caused abandonment of Site 388 (lower continental rise hills) after we had penetrated only into the mid-Tertiary sediments. And malfunctions of the pressure core barrel caused us to eliminate the Blake-Bahama Outer Ridge site entirely. Finally, repeated failures to re-enter the hole in the Blake-Bahama Basin (Site 391) required us to drill that site with a single bit. This bit penetrated to a record-setting 1412 meters depth, but the lowermost cores contained Upper Jurassic, rather than the older Jurassic sediments we had sought, and drilling ceased some 300-400 meters above the apparent basement reflector.

Yet by any reasonable standards the cruise was a scientific success. Because of careful planning by the JOIDES Atlantic Panel, the deep sites (388 and 391) were multipurpose and consequently, despite our failure to reach basement at these sites, the upper sections yielded valuable new data in both cases. Moreover, the drilling on the Blake Nose accomplished all our goals in that area.

OBJECTIVES AND PRINCIPAL RESULTS

Lower Continental Rise Hills (Site 388)

Long, low ridges with ridge and swale topography are a distinctive geomorphic feature of the lower part of the continental rise east of the United States and are especially prominent in the area of Site 388. Origins suggested for the ridge and swale topography are (1) construction of mud ridges by contour currents flowing along the base of the continental rise; (2) erosion by bottom currents; and (3) down-slope slumping and sliding.

As noted above, mechanical difficulties forced early abandonment of Site 388. The hole terminated at 341 meters in middle Miocene greenish gray hemipelagic mud. But this section, combined with the good seismic reflection profiles recorded by *Glomar Challenger* during the site survey, yielded information and inferences about the hills as follows: (1) the upper beds are apparently conformable with the topography which virtually eliminates erosion as an origin for the swales; (2) inclined structures in Pliocene and upper Miocene beds overlie an upper Miocene reflecting horizon which is essentially planar. Sediments recovered from this reflector show delicate bedding and burrow structures and *no* evidence of shearing or folding. This indicates the reflector is not a décollement at the toe of a major slide; (3) the seismic profile shows synclinal bedding beneath some ridge crests. This is compatible with the hypothesis that mud dunes were constructed by contour currents because such ridges would probably have dipping axial planes. Rotation of local slump blocks, however, could also explain the phenomenon.

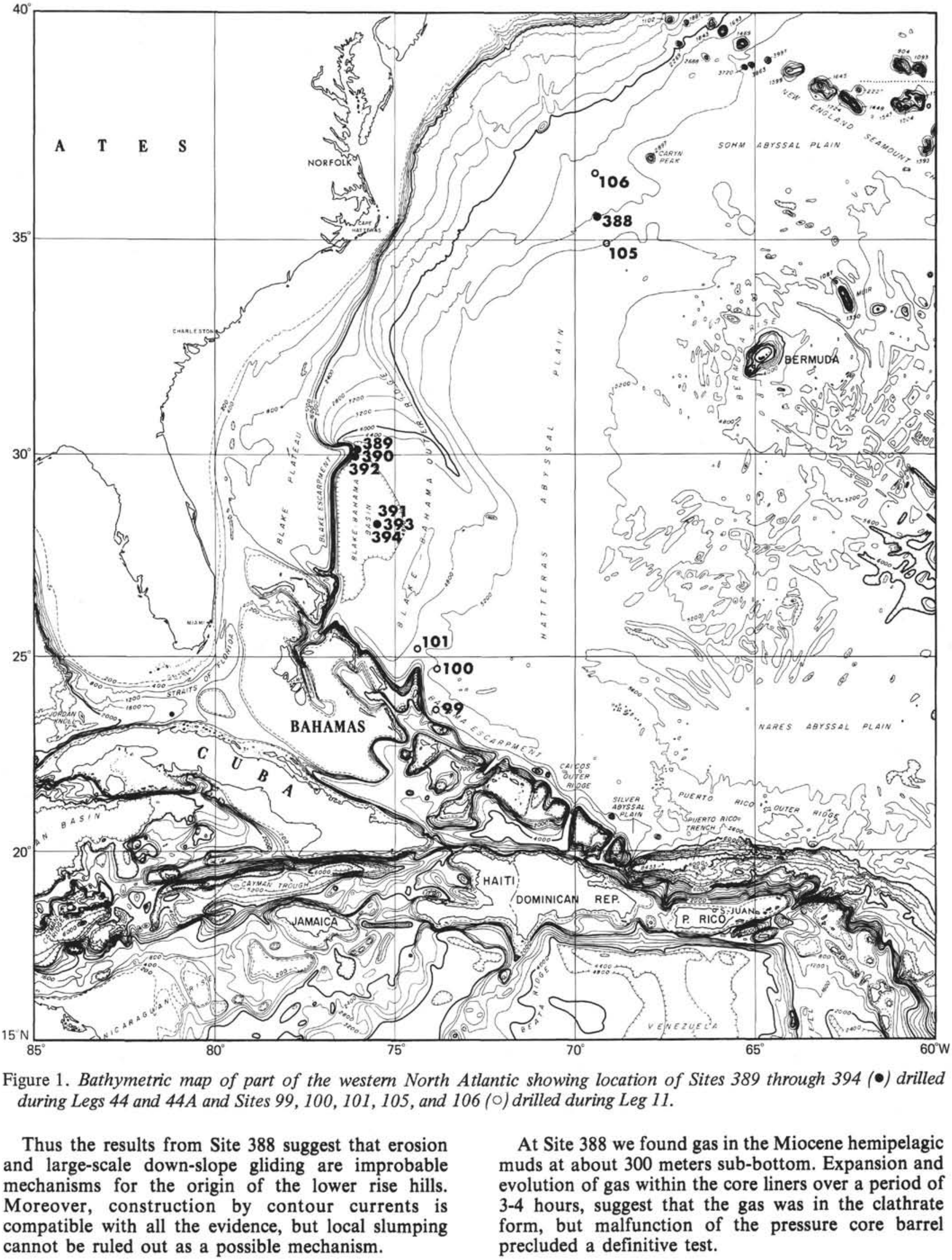

Figure 1. *Bathymetric map of part of the western North Atlantic showing location of Sites 389 through 394 (●) drilled during Legs 44 and 44A and Sites 99, 100, 101, 105, and 106 (○) drilled during Leg 11.*

Thus the results from Site 388 suggest that erosion and large-scale down-slope gliding are improbable mechanisms for the origin of the lower rise hills. Moreover, construction by contour currents is compatible with all the evidence, but local slumping cannot be ruled out as a possible mechanism.

At Site 388 we found gas in the Miocene hemipelagic muds at about 300 meters sub-bottom. Expansion and evolution of gas within the core liners over a period of 3-4 hours, suggest that the gas was in the clathrate form, but malfunction of the pressure core barrel precluded a definitive test.

TABLE 1
Leg 44 Coring Summary

Hole	Latitude	Longitude	Water Depth (m)	Penetration (m)	No. of Cores	Cored (m)	Recovered (m)	Recovery (%)	Oldest Sediment
388	35°31.33'N	69°23.76'W	4919	25.0	1	0.0	0.0	0	–
388A	35°31.33'N	69°23.76'W	4919	341.0	11	98.5	42.9	44	Middle Miocene
389	30°08,54'N	76°05.57'W	2714	40.0	1	9.5	3.5	37	Holocene
390	30°08.54'N	76°06.74'W	2665	206.0	10	92.0	27.2	30	Lower Cretaceous (pre-Barremian)
390A	30°08.54'N	76°06.74'W	2665	142.5	14	133.0	86.8	65	Lower Cretaceous (Albian)
391	28°13.73'N	75°36.76'W	4961	4.5	1	4.5	2.3	51	Quaternary
391A	28°13.61'N	75°37.00'O	4974	658.5	21	199.5	129.96	65	Upper Cretaceous
391B	28°13.61'N	75°37.00'K	4974	9.5	1	9.5	9.3	98	Quaternary
391C	28°13.61'N	75°37.00'M	4974	1,412.0	54	501.0	216.25	43	Upper Jurassic
392	29°54.48'N	76°10.50'W	2605	60.0	2	12.5	3.2	26	Lower Cretaceous
392A	29°54.63'N	76°10.68'W	2601	349.0	33	282.5	25.4	9	Lower Cretaceous
Totals						1342.5	546.81	41	

TABLE 2
Leg 44A Coring Summary

Hole	Latitude	Longitude	Water Depth (m)	Penetration (m)	No. of Cores	Cored (m)	Recovered (m)	Recovery (%)	Oldest Sediment
393	28°11.80'N	75°35.94'W	4951	8.0	1	8.0	4.3	46	Quaternary
393A	28°11.80'N	75°35.94'W	4951	58.5	1	–	9.5	–	Quaternary
393B	28°11.80'N	75°35.94'W	4951	0.0	0	0.0	0.0	0	–
394	28°11.70'N	75°35.76'W	4957	83.5	0	0.0	0.0	0	–
394A	28°11.70'N	75°35.76'W	4957	364.5	6	55.0	17.3	31	Miocene
Total						63.0	31.1	49	

Blake Nose (Sites 389, 390, and 392)

Reef-like structures of Cretaceous age form a complex chain that girdles the Gulf of Mexico from Mexico through Texas and Louisiana and apparently extends through Cuba and the Bahamas. What appear to be reefs of similar age have been tentatively identified from seismic profiles and samples dredged from along the edge of the Blake Plateau and offshore from Cape Hatteras to as far north as the Georges Bank. One supposed occurrence of this reef bank is on the Blake Nose—a northeast-jutting spur of the Blake Plateau about 250 miles east of St. Augustine.

Our three major objectives in drilling the Blake Nose area were to (1) study the lower Tertiary section to identify known reflectors of regional extent across the Blake Plateau; (2) investigate the presence of the supposed Cretaceous reef bank below the rough reflector; and (3) determine the age and history of the supposed reef bank and resulting facies changes. Following the advice of the JOIDES panel on safety and pollution, we limited drilling to sites near the lip of the escarpment to avoid penetrating structural closure in beds of unknown composition, and to penetrate the possible reefal deposits only where they would have been subjected to salt-water flushing.

Hole 389 was an abortive attempt to spud in near the northeast rim of the Blake Nose and resulted only in a bent bumper sub (bottom of drill pipe) which apparently resulted when the bit skidded along a lag gravel of hard manganese nodules and shell fragments—a testament to the effectiveness of ocean currents at 2700 meters depth.

Drilling at Site 390 on the north rim, and at Site 392 on the south rim, showed that the Blake Nose is directly underlain by middle Eocene to upper Barremian pelagic carbonate oozes. Shallow-water limestones typical of carbonate banks lie immediately below the ooze at Site 390. At Site 392 back-reef to near-shore environments underlie the ooze. About 250 meters of this reefal platform limestone were penetrated in Hole 392A. All the limestone has been recrystallized and much of it shows evidence of subaerial weathering and leaching by fresh water. The upper surface is capped by a brecciated oxidized zone with small brown pisolites of goëthite. The limestone was probably deposited during the Early Cretaceous (Neocomian and possibly early Barremian). After its last exposure above sea level the area sank rapidly, for the overlying Aptian-Albian oozes are definitely pelagic, and probably were deposited in water more than 500 meters deep.

The oozes are particularly noteworthy because there is a nearly complete sequence of middle Eocene through Maestrichtian sediments with few hiatuses at Site 390. Much of the section contains a varied faunal assemblage that allows intercomparison of radiolarians, foraminifers, and nannofossils. Moreover, we found a major unconformity between the Campanian seismic reflection profile across the Blake Nose suggests that this is an angular unconformity and that some of the missing Upper Cretaceous sections may be present in the middle part of the nose. The unconformity provides evidence of strong bottom currents in the area during some pre-Campanian time. The two prominent reflectors above the reef-bank facies appear to correlate with the pre-Campanian unconformity and with a zone of semilithified and partly chertified Paleocene ooze.

Blake-Bahama Basin (Site 391)

The Blake-Bahama Basin is a prominent abyssal area in the western North Atlantic Ocean. It is of particular geologic interest because it probably contains the oldest sediments still extant in any ocean basin and overlies the western part of the so-called magnetic quiet zone.

Several prominent reflecting horizons underlie the basin. The uppermost crops out at the base of the Blake escarpment, where it had been identified as an upper Miocene carbonate turbidite. Below this, at a probable sub-bottom depth of about 650 meters, Horizon *A* is such a strong reflector that only a few reflecting systems had penetrated below it to Horizon Beta at about 1100 meters sub-bottom.

During previous DSDP cruises, especially Leg 11, drilling around the margin of the basin recovered Upper Jurassic sediments above basaltic basement. However, penetration of the thicker section in the deeper central part of the basin had awaited development of the capability to re-enter the hole (to allow replacement of worn bits) and more definite geophysical profiles that would show depth to basement. The latter was supplied just before the beginning of Leg 44 by the Institute Français du Pétrole/U.S. Geological Survey.

Site 391 was therefore drilled near the center of the Blake-Bahama Basin to: (1) correlate the prominent reflecting horizons with lithology; (2) determine the character of Cenozoic sedimentation, especially the extent and thickness of possible Miocene carbonate turbidites; (3) confirm the presence of and sample Cretaceous and Upper Jurassic sections; (4) search for Middle and possible Lower Jurassic strata; and (5) determine the age and character of the basaltic basement, both as an aid in understanding the nature of the magnetically quiet zone and in calculating Jurassic spreading rates.

Inability to re-enter the hole precluded changing bits, and we ultimately drilled a single-bit hole (391C) that ended with destruction of the bit at 1412 meters sub-bottom. Although this was a record for penetration, the hole terminated in hard red marly Upper Jurassic limestone, 300 meters or more above probable basement. Thus, objectives 4 and 5 of our original program were unfulfilled. Yet several significant—even spectacular—findings emerged from the record-breaking hole.

Because of the scientific importance of completing the work at Site 391, this same area of the Blake-Bahama Basin was chosen for drilling during Leg 44A. Actual core recovery, however, was minimal. We recovered only nine cores from three holes at Sites 393 and 394. They contained Quaternary calcareous clay and ooze and Miocene intraclastic chalks which correspond to the gravity-flow sequence from the upper part of Site 391.

Lithology

Cenozoic Sedimentation

As shown in Figure 2, the top 150 meters consist largely of gray hemipelagic mud of Quaternary and uppermost Miocene age; the Pliocene is missing. Below this mud is a remarkable 500-meter section of Miocene carbonate gravity-flow deposits. A few beds show the characteristic graded bedding of turbidites, but most are massive chalk breccias with angular clasts of green and brown radiolarian-rich clay—also of Miocene age (Figure 3). These chalk breccias rest unconformably on Upper Cretaceous variegated and black carbonaceous clays. No Eocene or uppermost Cretaceous beds are present, although some microfossils of that interval have been carried into the chalks from nearby shallow sources. We interpret these turbidites and breccias as dense submarine gravity-flow deposits derived from both the shallow Bahama Banks and the somewhat deeper Blake Plateau. The gravity flows may have been triggered by tectonic activity, lowering of sea level, or both.

Geochemical analysis of the hydrocarbon maturation with depth in the Cretaceous clays suggests that this unit was buried by at least 800 meters of sediment which was removed by erosion before Miocene sediments were deposited. Removal of the overlying sediments is evidenced by the presence of clasts of non-calcareous Miocene clay and Cretaceous through Oligocene microfossils reworked into the overlying Miocene turbidites.

Cretaceous Carbonaceous Shales

Underlying the Miocene chalk breccias is black, sulfide-bearing claystone that typifies much of the middle Cretaceous of the North Atlantic. At Site 391 these beds are 275 meters thick and are essentially carbonaceous clays. The upper part is unfossiliferous except for a few dinoflagellates The lower part contains Albian nannofossils.

Lower Cretaceous/Upper Jurassic Section

The carbonaceous claystone grades downward into 75 meters of Albian-Aptian calcareous claystone, which then gives way to 370 meters of gray and white, somewhat clayey, limestone. The detailed lithology of these Barremian (Lower Cretaceous) through lower Tithonian (Upper Jurassic) sediments is quite varied. One sequence at about 1100 meters has thin, varve-like laminations. The sequence, which was cored continuously, is about twice the thickness of the equivalent strata at Sites 99, 100, and 101 (Leg 11) and represents the most complete section of Neocomian-Tithonian beds thus far sampled. Except for one zone in the Barremian sediments, all recognized nannofossil zones are present. The Cretaceous-Jurassic boundary is contained within a continuously deposited sequence.

The bottom 50 meters of the limestone is variegated and grades downward into 40 meters of lowermost Tithonian dark purplish red, very hard, marly

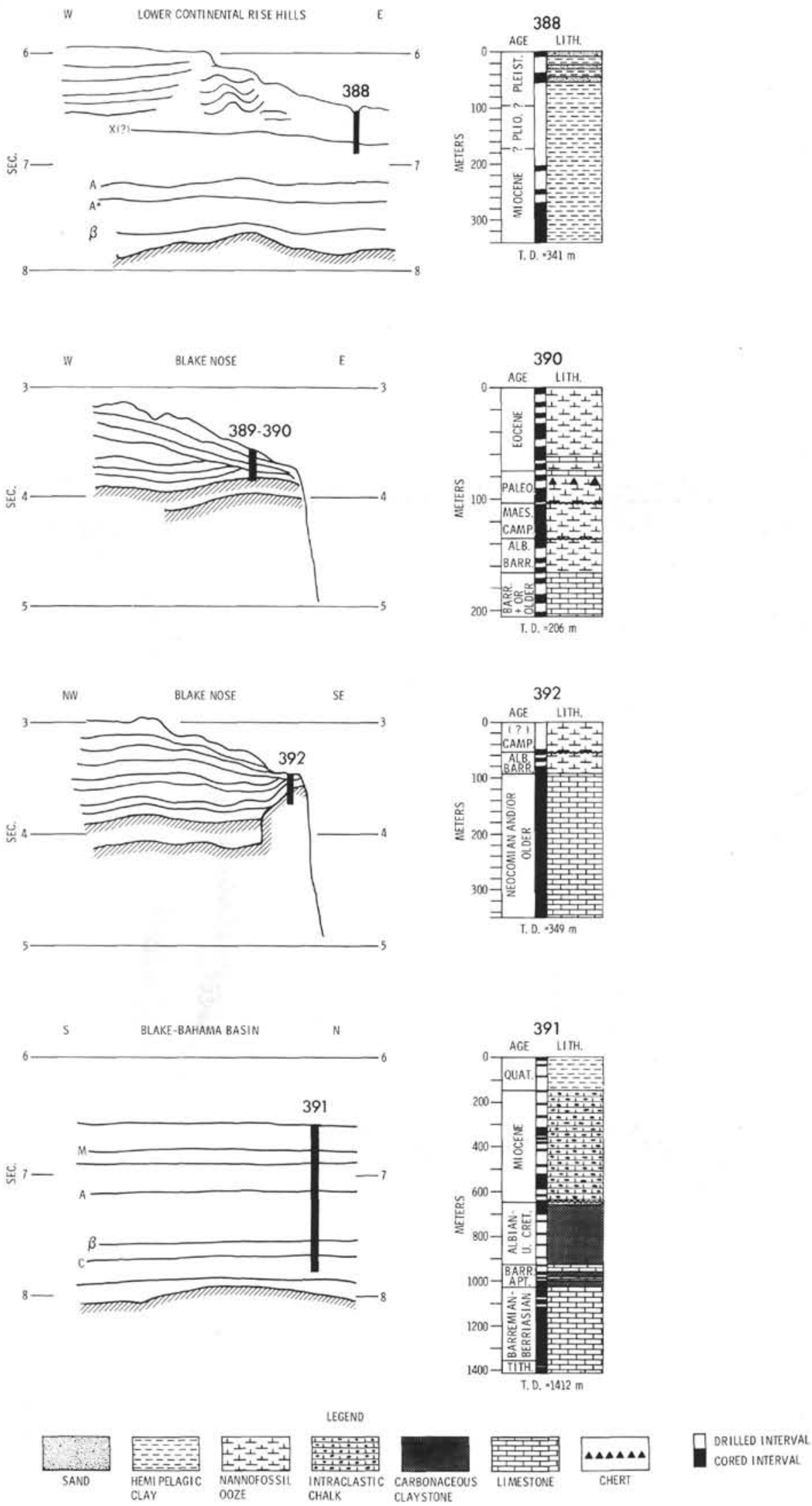

Figure 2. *Stratigraphic sections and tracings of seismic profiles for sites drilled during Leg 44. Numbers along sides of profile are two-way reflection times in seconds.*

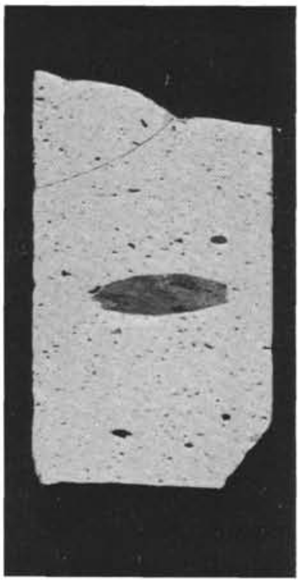

Figure 3. *Intraclastic chalk breccia with clasts of green and brown radiolarian-rich clay from Miocene gravity-flow deposits in the Blake-Bahama Basin (Sample 391C-2-3, 122-132 cm).*

limestone. Although the limestone is quite hard, the formation is thinly bedded and fissile. Ammonites, some with nacreous luster, are common. The overall appearance of the sequence is remarkably like that of the Jurassic of the Mediterranean region (the *ammonitica rosso*).

Reflecting Horizons

Four of six prominent sub-bottom reflectors were identified and correlated with lithology; the bottom two reflectors (including basement) were not penetrated. The uppermost reflector, M, at 150 meters, is the top of the Miocene turbidite sequence. Horizon Beta, at about 1000 meters, marks the transition from Aptian clay to Neocomian limestone, and a lower reflector, horizon C, apparently corresponds with the top of the red marl.

A very strong reflector at about 650 meters sub-bottom has previously been correlated with horizon *A* of the North Atlantic. But horizon *A* is, in many places, Eocene chert, and lower Tertiary beds are missing at Site 391. The reflector here marks the unconformity between the Miocene chalk breccia and the underlying Cretaceous clay. The apparent velocity inversion below the chalks probably enhances the strength of the reflector.

REFERENCES

The western North Atlantic has been studied by many investigators and the background data for Leg 44 were derived from many sources. These are referenced in detail in the Site Reports and special chapters of this volume, and we acknowledge these only in total and in general.